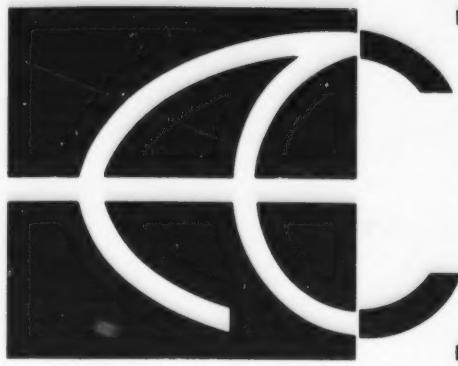

AGRICULTURAL ENERGY CENTRE

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SEALING AND INSULATING
SPECIFIC AREAS OF
BULK TOBACCO KILNS

Report No. 88-6507 APRIL, 1988

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SEALING AND INSULATING
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BULK TOBACCO KILNS

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By:

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ABSTRACT

The energy and cost effectiveness of applying a 25 mm thickness of polyurethane foam to the roof, blower/burner wall, sheet metal above the blower/burner and base of five bulk kilns was evaluated. The cost of the polyurethane foam application was $600 per bulk kiln. As compared to five check kilns at the same site, a natural gas saving of 17% was realized. The simple payback period for the insulation retrofit would be about 7 curing seasons. If the bulk kilns had been fuelled by propane, the simple payback period would be about 4 curing seasons.

PROBLEM IDENTIFICATION

The majority of bulk tobacco kilns, manufactured prior to the 1980's, were constructed of metal roofing, insul-board and wood rafters in the roofs. Today, some tobacco growers with bulk kilns constructed with this type of roof are experiencing problems curing and conditioning their tobacco. Figure I illustrates how poorly the insul-board has withstood the high humidity conditions during tobacco curing and conditioning processes.

Insul-board has a permeability of 13 to 33 grams/(24 h $m^2 \cdot mm \cdot Hg$). During the yellowing phase of tobacco curing, when the relative humidity is maintained between 80 and 93%, water vapor travels through the insul-board and condenses on the underside of the metal roof. In turn, the insul-board absorbs the water droplets and becomes heavier. This is repeated again during the tobacco conditioning process when high levels of humidity are maintained. Eventually the insul-board sags because of the added weight and separates from the metal roof and rafters.

Many serious problems are created when sheets of insul-board separate and hang from the sheet metal roof of a bulk kiln: the air pattern in the upper plenum of the kiln is disrupted; air circulating in the upper plenum of the kiln cools as it passes over exposed areas of the metal roof; and high levels of humidity are difficult to maintain during curing and conditioning because of air exfiltration occurring where the exposed metal roofing sheets are overlapped. These problems result in inefficient curing and poor control over the curing and conditioning processes which could affect tobacco quality.

A project was undertaken in 1987 which investigated the benefits resulting from removing the insul-board and applying polyurethane foam to the underside of the metal roof. In addition, other areas of a bulk kiln that were not sealed and insulated during construction were retrofitted with polyurethane foam: steel base; blower/burner wall; and sheet metal above the blower/burner unit.

The mention of manufacturer's trade names is for the purpose of specific product description and does not indicate endorsement or criticism of that product or products not mentioned by the author or the Ontario Ministry of Agriculture and Food.

OBJECTIVE

The objectives of the project were:

1) to determine the energy and cost effectiveness of sealing and insulating different areas of bulk kilns;
2) to determine if sealing and insulating different areas of bulk kilns would improve control of air exchange rates and the quality of cured tobacco.

METHOD

Site

A demonstration project was conducted at the farm of John Tamscu, R. R. # 2, Courtland. The farm is equipped with ten "Powell" bulk kilns that were manufactured in 1977 and 1978. Each kiln is equipped with 150 racks; a 295 megajoule per hour burner fuelled by natural gas; and a squirrel-cage blower powered by a 3.7 kW motor.

The construction of each kiln is similar. The roofs are constructed of 50 mm x 100 mm rafters, 20 mm thick insul-board (RSI 0.36) and metal roofing. The sidewalls are constructed of 95 mm thick plywood, 50 mm thick fiberglass insulation (RSI 1.03), 50 mm x 100 mm studs and metal siding. The blower/burner walls are constructed of 95 mm thick plywood and 50 mm x 100 mm studs.

Sealant and Insulation

It was decided that polyurethane foam would be the most appropriate material for this type of application. Polyurethane foam has many positive attributes: adheres to almost any surface; forms a monolithic layer which prevents air exfiltration and infiltration; impervious to water penetration; and a 0.43 RSI per cm of thickness.

Polyurethane Foam Application

The ten bulk tobacco kilns on the Tamscu farm are situated in a single row. During harvest, the bulk kilns are loaded consecutively starting at one end of the row. Five of the bulk kilns, every other kiln in the row of ten, were selected as test kilns that would be sealed and insulated with polyurethane foam. The other five bulk kilns were not modified and served as check kilns.

The bulk kilns were selected in this manner so that a representative cross-section of the entire tobacco crop would be cured in the test and check kilns. This would also reduce the difference in ambient (outside) temperature between cures in the test and check kilns.

The insul-board was removed from the roofs of the five test kilns. Removing the insul-board left a 20 mm space between the rafters and the metal roofing. The metal roofing was re-nailed to the rafters to eliminate the space. A 25 mm thickness (1.08 RSI) of polyurethane foam was sprayed on the underside of each kiln roof (see figure 2). The eave cavity (where the roof joins the wall) was filled with polyurethane foam as well.

The perforated floor was removed from each test kiln. The perimeter of the steel base (C-channel) was scrapped free of rust, painted and sprayed with polyurethane foam to a thickness of 25 mm (see figure 3). The bottom lip of the C-channel, where it rests on the concrete pad, was also sealed with polyurethane foam.

In addition, each kiln had a 25 mm thick application of polyurethane foam applied to the wall which separates the curing compartment from the blower/burner unit. The polyurethane foam was applied to the blower/burner side of the wall.

The last location sealed and insulated with a 25 mm thick application of polyurethane foam was the underside of sheet metal above the blower/burner unit of each kiln.

The cost of the polyurethane foam which included application was $600 per bulk kiln and totalled $3,000 for the five bulk kilns.

It should be noted that since polyurethane is combustible care was taken to prevent any of it from entering the blower/ burner unit. Application of a coating to protect the polyurethane foam from ultra-violet rays was not necessary since it would not be exposed to direct sunlight in the interior of the kiln.

MONITORING

Parameters monitored during each cure in the test and check kilns were as follows:

i) natural gas usage;

ii) cured tobacco weight and grade index;

iii) general weather observations and any unusual occurrences.

EVALUATION AND RESULTS

Energy Effectiveness

A total of 35 cures were monitored, 17 cures in the test kilns and 18 cures in the check kilns. The data collected from each cure is summarized in appendix 1.

Figure 4 illustrates the fuel energy usage (megajoules, MJ) per kilogram of cured tobacco for each cure in the test and check kilns. The graph indicates that the majority of cures in the test kilns required less energy than the cures in the check kilns.

Over the 18 cures in the check kilns, 16 535.1 m^3 of natural gas was consumed per 21 284 kg of cured tobacco. This equates to an energy usage of 29.3 MJ per kg of cured tobacco (assuming the energy content of natural gas is 37.7 MJ/m^3). Over the 17 cures in the test kilns, 12 675.0 m^3 of natural gas was consumed to cure 19 633 kg of cured tobacco. This equates to an energy usage of 24.3 MJ per kilogram of cured tobacco. Thus, cures in the test kilns consumed on average 17% less energy.

Curing and Conditioning Processes

The cooperator used his own judgement in selecting each kiln's curing schedule. He noted a significant improvement in the control of air exchange rates in the test kilns as compared to the check kilns. This had no effect on the length of time to cure the tobacco in the test kilns. Over the course of the curing season, the test kilns cured for 244.4 hours on average, while the check kilns cured for 244.3 hours on average.

The time required to condition the tobacco in the test kilns was 4 hours less than in the check kilns. The conditioning period averaged 15.7 h per cure in the test kilns as compared to 19.7 h per cure in the check kilns. The reduction in time required for conditioning can be attributed to the polyurethane foam's sealing characteristics which prevented leakage of moisture-laden air.

Tobacco grades (see appendix 1), as judged by the cooperator, were similar between comparable cures in the test and check kilns. There does not appear to be any evidence that cured tobacco quality was improved because of improved control of air exchange rates during curing in the test kilns as compared to the control kilns. Comments by the cooperator indicated that the maturity of the tobacco was the most critical factor affecting cured tobacco quality.

Cost Effectiveness

Curing in the test kilns consumed, on average, approximately 0.131 m^3 less natural gas per kilogram cured than in the check kilns. Based on a cost of \$0.173 per m^3 of natural gas and an average of 1155 kg of cured tobacco per test kiln, about \$26.18 was saved per cure. Thus, over the 17 cures in the five test kilns, about \$445 was saved.

The simple payback period would be:

Simple Payback = cost/(savings/year)
= \$3000/(\$445/y)
= 6.7 years or about 7 curing seasons

If the test kilns were fuelled by propane, the annual savings would be about \$875 (assuming: propane burners operate at the same combustion efficiency; 25.5 MJ/L of propane; and cost of propane \$0.23/L). The simple payback period would be:

Simple Payback = cost/(savings/year)
= \$3000/(\$875/y)
= 3.4 years or 4 curing seasons

CONCLUSIONS

1) The insulation retrofit reduced curing fuel consumption by 17%.
2) The insulation retrofit did not affect the quality of cured tobacco.
3) The time required to condition tobacco in the insulated kilns was reduced by an average of 4 hours per cure as compared to the check kilns.
4) Control of air exchange rates was improved in the insulated kilns.

5) The cost to retrofit each bulk kiln with polyurethane insulation amounted to $600. The savings in natural gas over the curing season amounted to $89 per kiln. The simple payback period is 7 curing seasons. If the bulk kilns were fuelled by propane the simple payback period for the insulation retrofit would be 4 curing seasons.

RECOMMENDATIONS

The Energy Centre should continue to monitor the durability of the polyurethane insulation over the next three curing seasons.

ACKNOWLEDGEMENTS

The author extends his thanks to: the cooperator, John Tamscu, for his valuable assistance in recording accurate curing data; and the Ministry of Energy for providing partial funding of the project.

Figure 1: Insul-board that has deteriorated and separated from the metal roof of a bulk kiln.

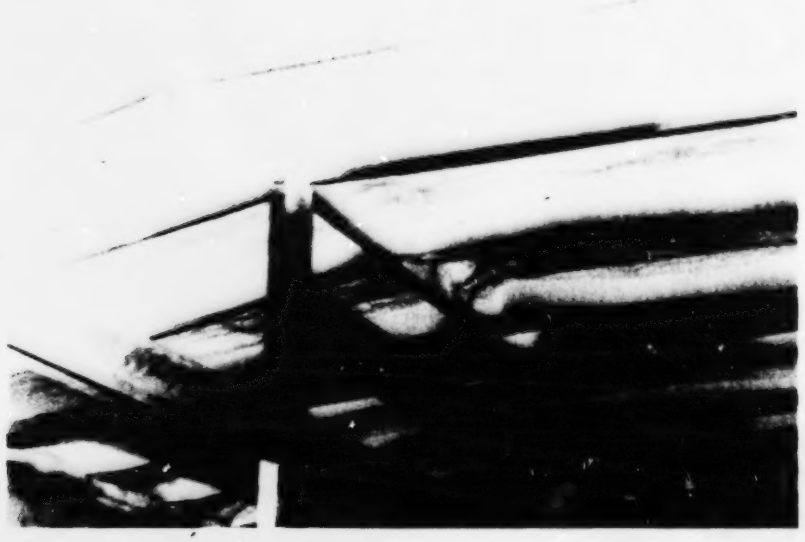

Figure 2: Polyurethane foam applied to the underside of the metal roof of a bulk kiln.

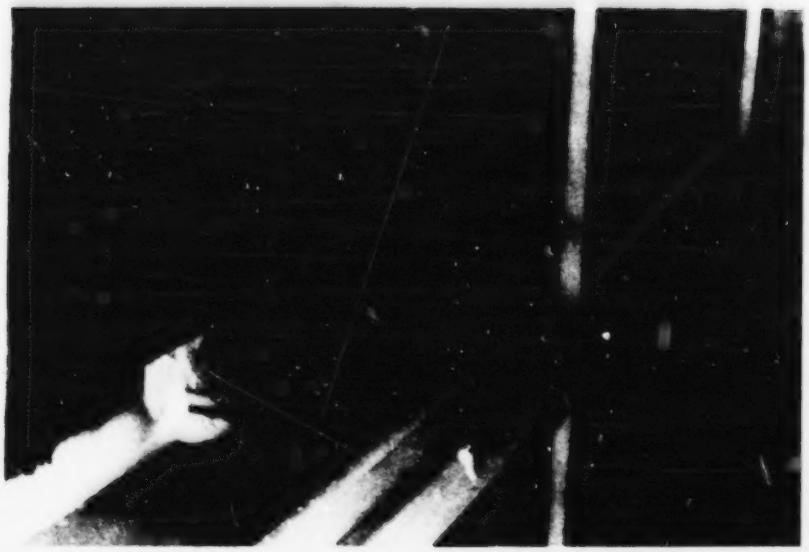

Figure 3: Polyurethane foam being applied to the steel base of a bulk kiln.

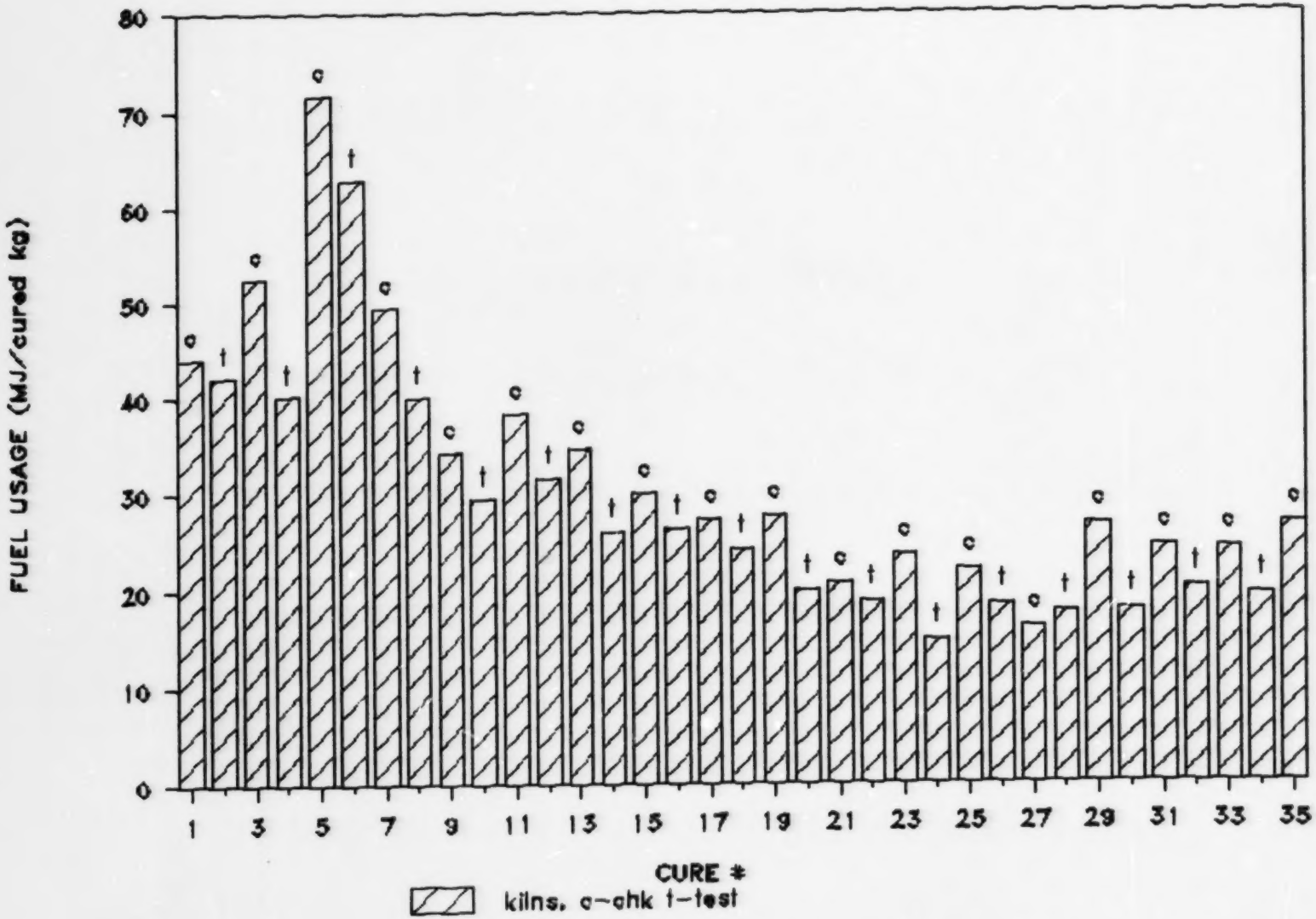

Figure 4: Energy consumption of cures in the test and check kilns

Appendix I: Curing Data

CURE AND KILN TYPE[1]	LEAF POSITION	CURE LENGTH (h)	GAS USAGE (m^3)	CURED MASS (kg)	TOBACCO GRADES (majority)	ENERGY PER MASS (MJ/kg)	COST PER MASS (¢/kg)
1c	sands	215	976.2	837	XL4	44.0*	20.2**
2t	sands	215	837.4	748	XL4	42.2	19.4
3c	sands	215	951.6	683	XL3	52.5	24.1
4t	sands	232	780.3	733	XL4	40.1	18.4
5c	sands	233	901.6	474	XL3	71.7	32.9
6t	sands	215	789.0	474	XL3	62.8	28.8
7c	sands	215	775.5	592	XL3	49.4	22.7
8t	sands & seconds	241	761.3	718	XL3	40.0	18.3
9c	seconds	245	884.2	971	CL2	34.3	15.8
10t	seconds	237	710.5	909	CL2	29.5	13.5
11c	seconds	240	931.0	919	CL4	38.2	17.5
12t	seconds & thirds	257	664.5	794	CF5	31.6	14.5
13c	seconds	257	1070.5	1166	CL2	34.6	15.9
14t	thirds	243	830.2	1207	CL2	25.9	11.9
15c	thirds	256	958.7	1202	CF4	30.1	13.8
16t	seconds & thirds	264	793.8	1134	CF3	26.4	12.1
17c	thirds	235	848.5	1170	CF3	27.3	12.5
18t	thirds	243	758.9	1179	CF3	24.3	11.1
19c	thirds	263	910.3	1236	CF3	27.8	12.7
20t	fourths	237	758.1	1427	BF2	20.0	9.2
21c	tips	236	882.6	1601	BF3	20.8	9.5
22t	fourths	238	710.5	1411	BF2	19.0	8.7
23c	fifths	229	935.7	1488	BF2	23.7	10.9
24t	tips	237	621.7	1565	BF3	15.0	6.9
25c	fourths	256	900.8	1529	BF3	22.2	10.2
26t	fifths	252	778.7	1581	BF2	18.6	8.5
27c	tips	251	715.3	1667	BF3	16.2	7.4
28t	fourths	255	670.9	1424	CF3	17.8	8.2
29c	seconds, thirds, fourths	257	931.7	1315	CF3	26.7	12.3
30t	tips	279	694.6	1456	BF3	18.0	8.3
31c	fourths	269	980.1	1510	CF3	24.5	11.2
32t	fifths	257	762.1	1415	CF3	20.3	9.3
33c	fourths	251	969.8	1504	CF3	24.3	11.2
34t	tips	257	752.5	1458	BF5	19.5	8.9
35c	tips	278	1011.0	1420	BF4	26.8	12.3

CURE AND KILN TYPE[1] - cure number and type of kiln, c-check, t-test

ENERGY PER MASS - fuel energy consumed per kg of cured tobacco

*ie (976.2 m^3 x 37.7 MJ/m^3) ÷ 837 kg = 44.0 MJ/kg

COST PER MASS - cents of fuel per kg of cured tobacco

**ie (976.2 m^3 x 17.3 $¢/m^3$) ÷ 837 kg = 20.2 ¢/kg

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